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CORNING GLASS WORKS

ELECTRO-OPTICS LABORATORY

RALEIGH, NORTH CAROLINA

IMPROVED SCREEN FOR REAR PROJECTION VIEWERS

Technical Report No. - 6

Date - January 17, 1966

Period Covered - December 15, 1965
to
January 15, 1966

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Technical Report #6

1. Theoretical Studies

A theoretical investigation was made concerning the feasibility of using vapor deposition techniques to place highly reflective coatings inside small hollow fiber tubes. We are starting preliminary laboratory studies of this approach based on the following considerations.

Vapor plating techniques use liquid organo-metallic compounds, whose vapors can be decomposed by heat leaving free metal. Transport of material into the fibers can be done either by bubbling a carrier gas through the liquid to pick up the vapor, or if it is not a liquid at room temperature the gas is diluted with a non-reactive carrier gas. The plating of a matrix of fibers can be accomplished by clamping it into a heater where the vapor can continuously flow through and simultaneously be broken down leaving a highly reflective coating. Flow of the gas can be achieved by creating a pressure differential, either by increasing the pressure above one atmosphere on one side of the tubes or by creating a partial vacuum on the other side. Vacuum techniques using mechanical pumps could give a maximum pressure difference of about 14 lbs/inch^2, which is adequate. Higher pressures could be obtained by using a pressure device on the one side and leave the low pressure side open to the atmosphere. If the vapor is highly reactive, which it generally is, then this is a more practical way of transporting the vapor through the hollow fibers and preventing any reaction inside the pumps. Care must be exercised in choosing the pressure difference so as not to exceed the physical strength of the fiber matrix at the required elevated temperature. This force is simply the product of the cross-sectional wall area, normal to the length of the fiber, and the pressure differential.

Regardless of how the pressure difference is created, the flow rate of the gas through the matrix is of prime importance. From the theory of incompressible flow through a hollow pipe[1] the flow rate Q is given as

$$Q = \frac{\pi r^{4} \ \Delta P}{8 \ L\mu}$$

where R is the radius of the tube, ΔP the pressure difference, L its length and μ the viscosity of the fluid.

Figure 1 gives the viscosity of several common gases as a function of their temperature.

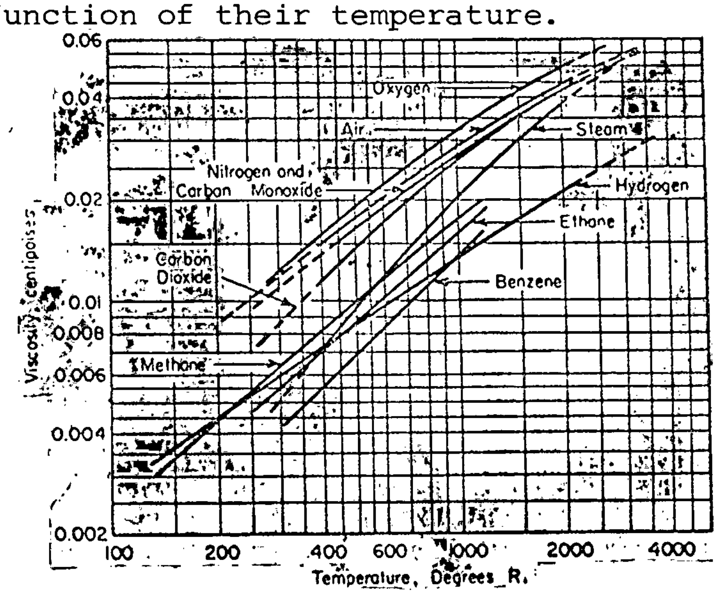

Figure 1. Viscosity of Some Common Gases

[1] Hermann Schlichting, Boundary Layer Theory, (McGraw Hill Book Co., New York, 1960).

To get some estimate of Q, Equ. (1) was evaluated using a value for μ of .01 centipoises and a length L of 5 mm for several pressure differentials and tube radii. The results are shown in Figure 2. The, R = 25 micron, dotted line is an extension of the R = 25 micron solid line. The scale for this and the R = 50 micron dotted line is given up the right edge of the figure, the scale for all other curves is up the left edge. The pressure difference is given in lbs/inch^2 with corresponding flow rates in cm^3/sec. The flow rate at a pressure differential of 14 lbs/inch^2 is 4.6×10^{-5} cm^3/sec assuming the fiber has a 5 micron inside radius. If they are 15 microns in outside diameter, a matrix one inch square will contain 2.9×10^6 fibers and have an acceptable total flow rate of 8 liters/min.

These data are based on a viscosity of .01 centipoise but even if the vapor of the organo-metallic material differs significantly from this, the result given here are not expected to be very different as the plating vapor can be diluted sufficiently by the carrier gas such that the final viscosity will still be near to the value assumed.

The one material which has been considered to aluminize with is tri-isobutylaluminum. It is a very reactive gas at room temperature, and decomposes into free aluminum and organic waste gasses between 230 and 290 degrees centigrade.

From these considerations this approach seems the most promising for coating the inside of hollow fiber tubes. This is primarily because of the better fluid properties of a gas as compared with a liquid. Other techniques for plating, such as ion sputtering and the "Hanovia Process" are still under laboratory investigation and will be reported on next period.

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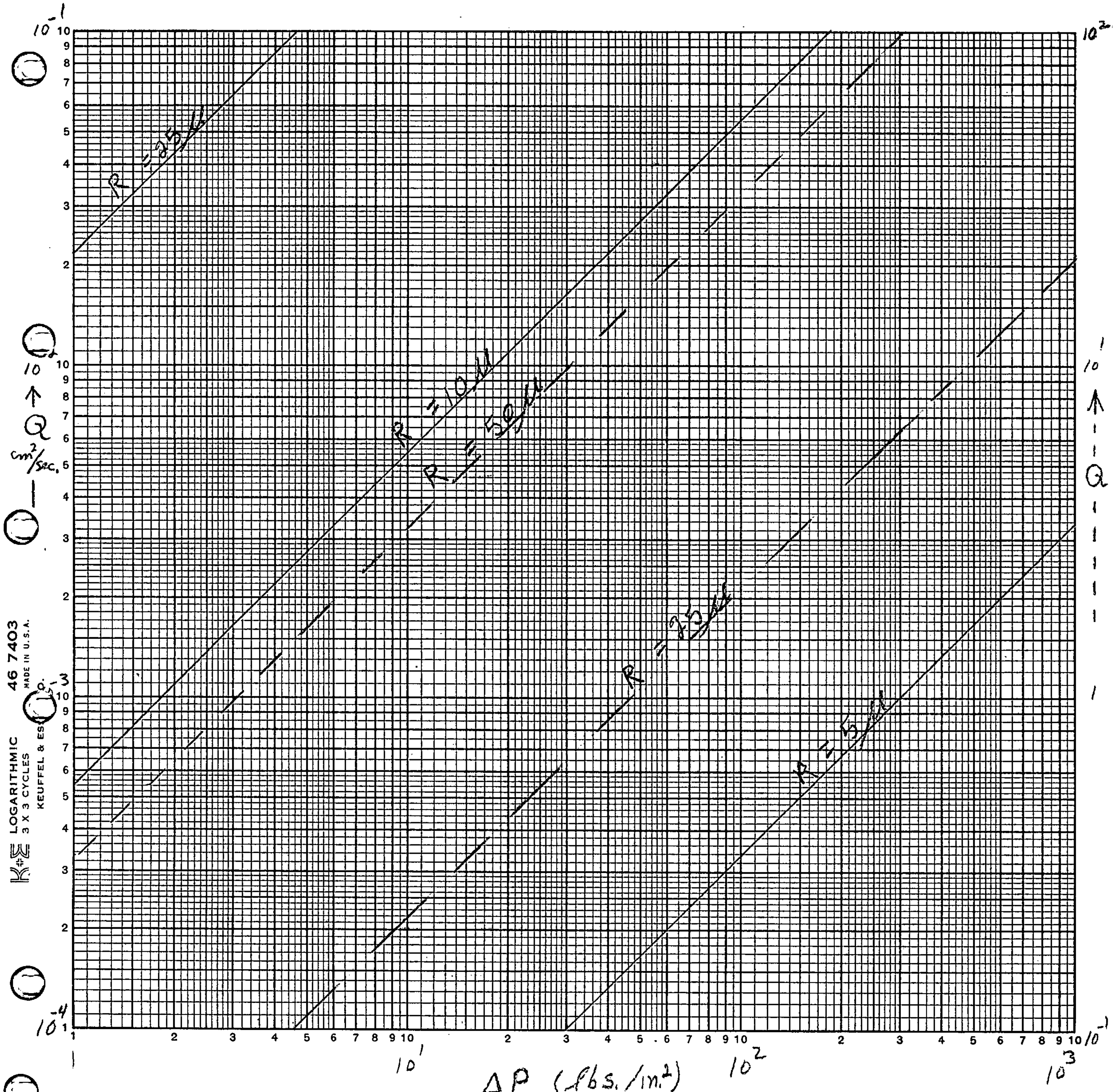

Figure 2. Flow Rate as a Function of Tube Radius and Pressure Difference

μ = .01 centipoise

L = 5 mm

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2. Investigations of Corning Glass Works Materials

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Preliminary investigations of the samples delivered last period indicate a wide range of particle sizes. The more dense samples had nearly spherical particles from 5 x 10^{-3} microns up to 2 microns in diameter. The less dense samples had particles so small they could not be seen with the electron microscope but were in the size range from 50 to 500 Angstroms as determined by their light scattering properties. Electron photomicrographs are being made of these samples and will be included in the next report. During the next period detailed spectrophotometric measurements of these samples will be made.

3. Instrumentation

A. Goniophotometer

A goniophotometer is being designed as a general laboratory instrument to get as much information as possible from the samples we test. It will have provision for making polarization and spectral investigations in addition to the angular scattering studies. Also, it will be equipped with both dry and liquid cells and measure light scattering from 0 to 150 degrees. The scanning of the scattered intensity distribution and subsequent data recording will be done automatically.

The design work is approximately 75 percent complete with construction about half finished. Because of delays in some of the components, we expect completion by March 1, 1966.

B. Modulation Transfer Function Analyzer

Design of a modulation transfer function (MTF) analyzer, to determine the characteristics of screen resolution, was started this period. Although we have done much theoretical work on such analyzers, little has been done up to this period on the design of such an instrument. The theory is straightforward but many practical considerations need to be made. We expect this to be a general enough instrument to measure the resolution properties of optical components as well as rear projection screens. Provision will be made to measure screen resolution for other than on axis viewing and with a projection geometry which duplicates conventional projection systems. A schematic of the analyzer is shown in Figure 3.

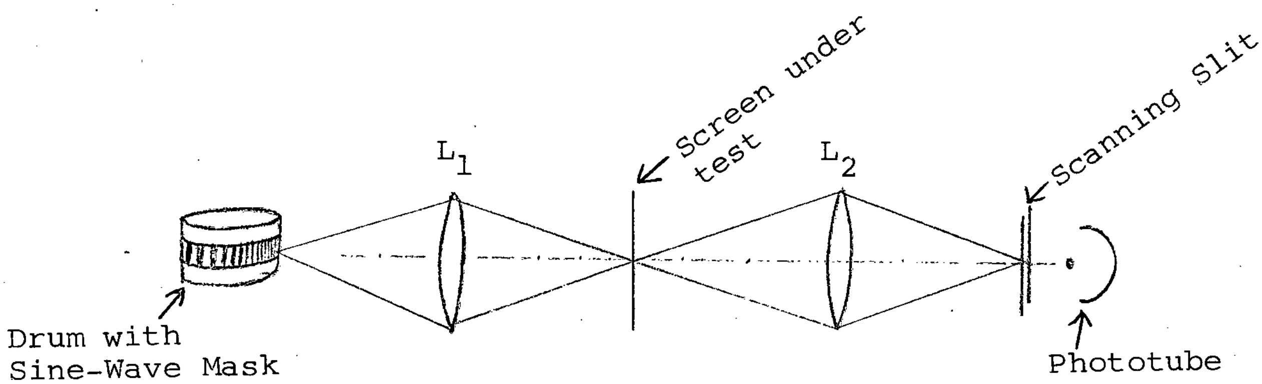

Figure 3. Schematic of MTF Analyzer

The object transparency is a special mask whose transmission is sinusoidal and has a linear increase of spatial frequency with length. A mask with similar properties is shown in Figure 4 for clarity.

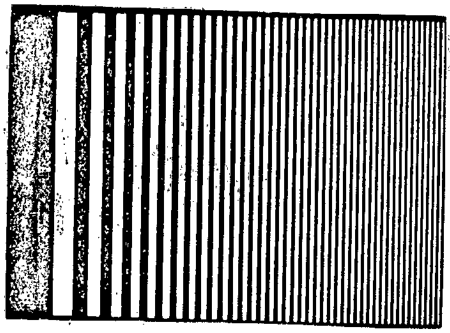

Figure 4

This is projected onto the sample of rear projection screen material by lens L_1. This image is then relayed to a narrow slit by a second lens L_2. As the drum rotates the image will move across the screen and also across the slit where the phototube converts the light intensity into electrical signals which are then processed with suitable electronics to give the contrast of the image on the screen as a function of spatial frequency. By removing the screen and measuring the resolution of just the two lens, their effects can be compensated for leaving just the resolution characteristics of the screen. Now that a given system design has been fixed we are proceeding with a more detailed design analysis.

C. Production of Sine-Wave Test Charts for the MTF Analyzer

The heart of the MTF analyzer is the sine-wave mask. The quality of the measurement made with the analyzer are strictly dependent on the quality of the sine-wave mask. Simple sine-wave patterns of constant spatial frequency are available but are very expensive and masks 10 to 20 inches long with a continuous variation in spatial frequency cannot be obtained. For these reasons we must make our own. Several techniques have already been discussed[2].

The technique first tried was to use an interferometer and simply record the interference pattern on film.

This was done, however many difficulties became evident. First the interference patterns were too small and more problems were created when we tried to expand them optically. Here the difficulty was immediately apparent. The spatial frequency of the fringes was so high that considerable contrast was lost because of the lens. Since the intensity distribution from the laser is not uniform but Gaussian, considerable expansion of the beam is necessary to get a large enough portion of it uniformly bright. Moreover, some of the advantages gained by using a laser source are apparently lost because of diffraction by apertures, shutters and specks of dust in the system. All of these effects can be seen in the sine-wave masks reproduced in Figure 5.

A much better way of making such masks is to draw the film past a slit which is being illuminated by a sinusoidally modulated light beam. The modulation can be produced by a wide variety of techniques of which direct modulation of the light source is one of the more important.

[redacted] "Improved Screen for Rear Projection Viewers", Technical Report No. 4, November 5, 1965.

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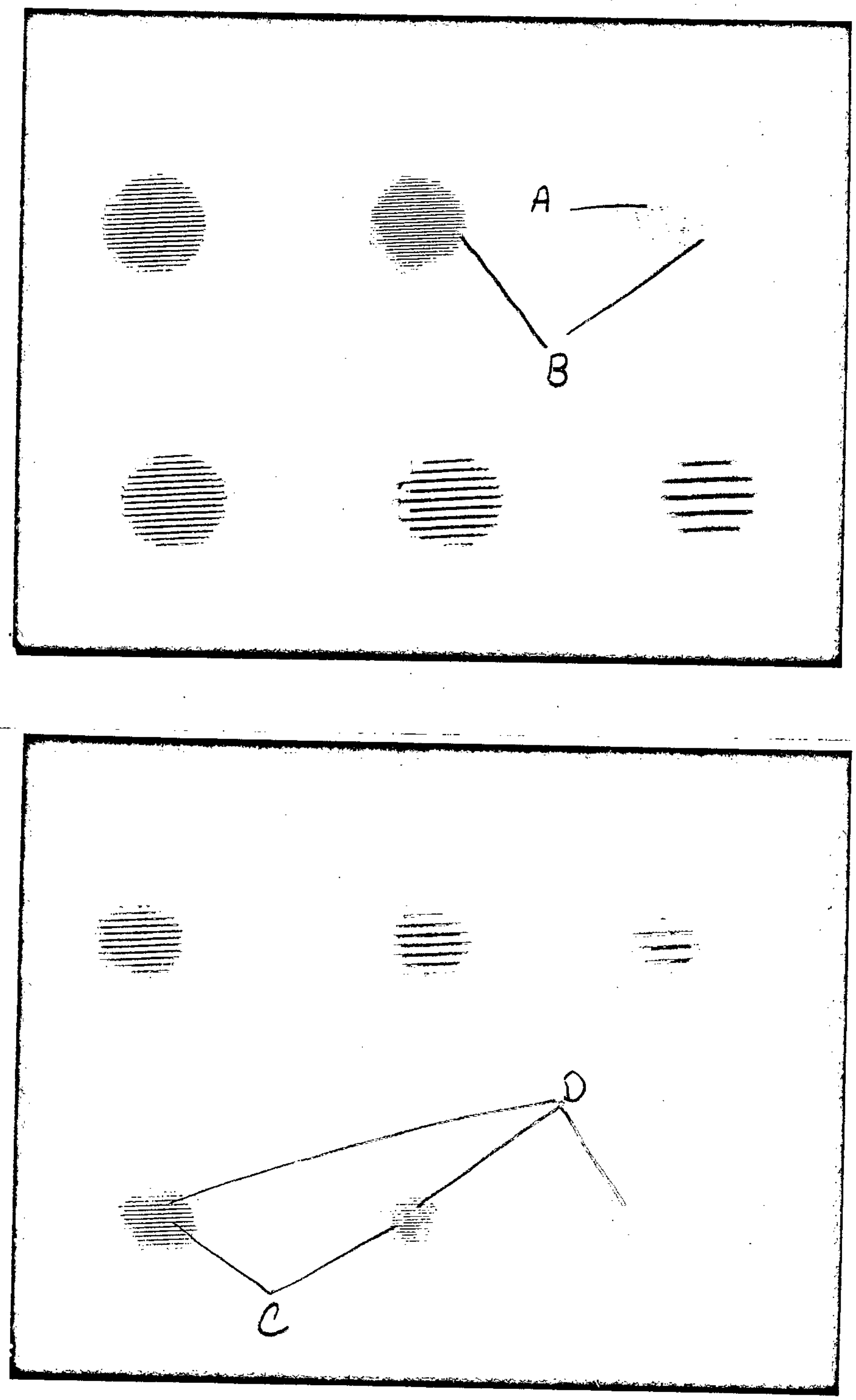

Figure 5. Degrading Effects Produced by an Interferometer Used in Producing Sine-Wave Masks.

A - dust specks.

B - diffraction by the aperture limiting the beam diameter.

C - Gaussian beam intensity.

D - nonuniform intensity distribution because of the shutter (effect not visible on these xerox copies).